

# Experiences from deep HST grism

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GRAPES: HUDF, G800 10 orbits x 4 PAs

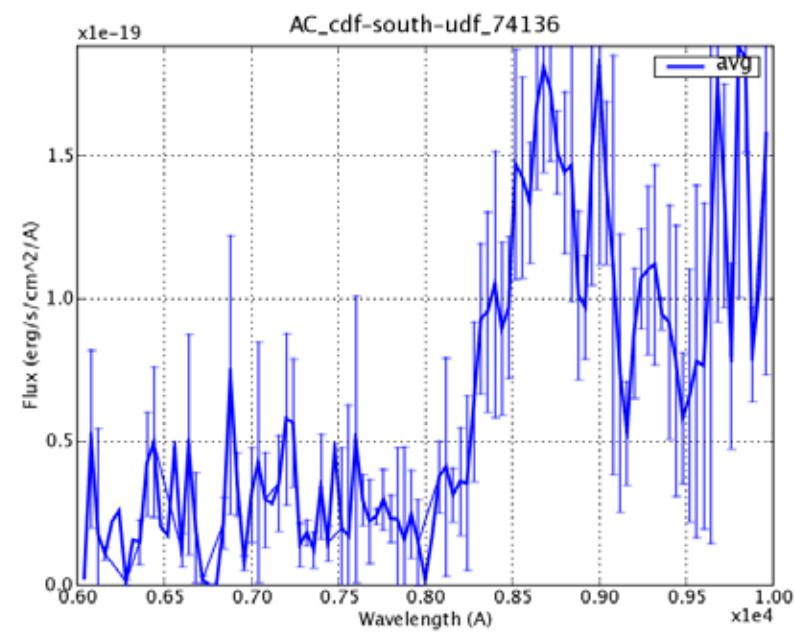
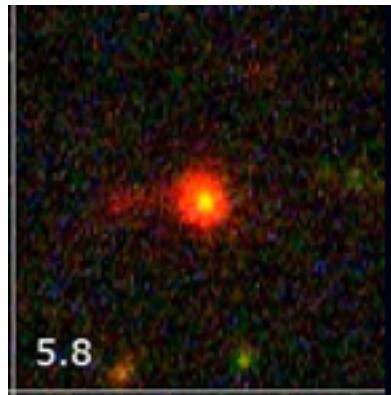
PEARS: G800, 8 fields to 5 x 4 PAs

FIGS: G102, 4 fields 8x5PAs

(Deep Imaging data from HST)



# Slitless spectroscopy





# GRism ACS Program for Extragalactic Science (GRAPES)

*Deepest Unbiased Spectroscopy yet.  $I(AB) < 27.5$   
To match the deepest imaging (Hubble Ultra Deep Field)*

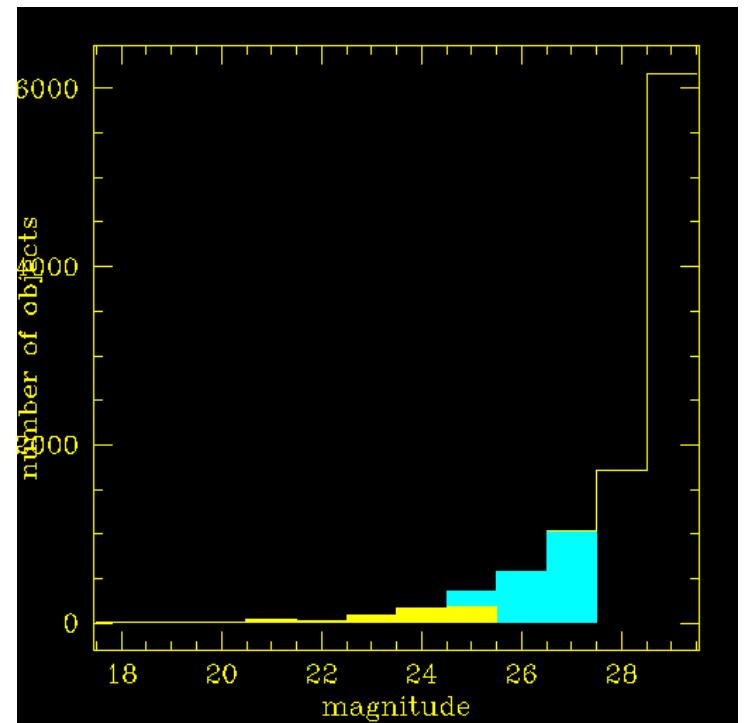


Team: S. Malhotra, James Rhoads, Nor Pirzkal, Chun Xu

A. Cimatti, E. Daddi, H. Ferguson, J. Gardner, C. Gronwall, Z. Haiman, A. Koekemoer, L. Moustakas,  
A. Pasquali, N. Panagia, L. Petro, M. Stiavelli, S. di Serego Aligheri, Z. Tsvetanov, J. Vernet, J.  
Walsh, R. Windhorst, H.J. Yan

# 40 orbits of UDF observations with the ACS grism

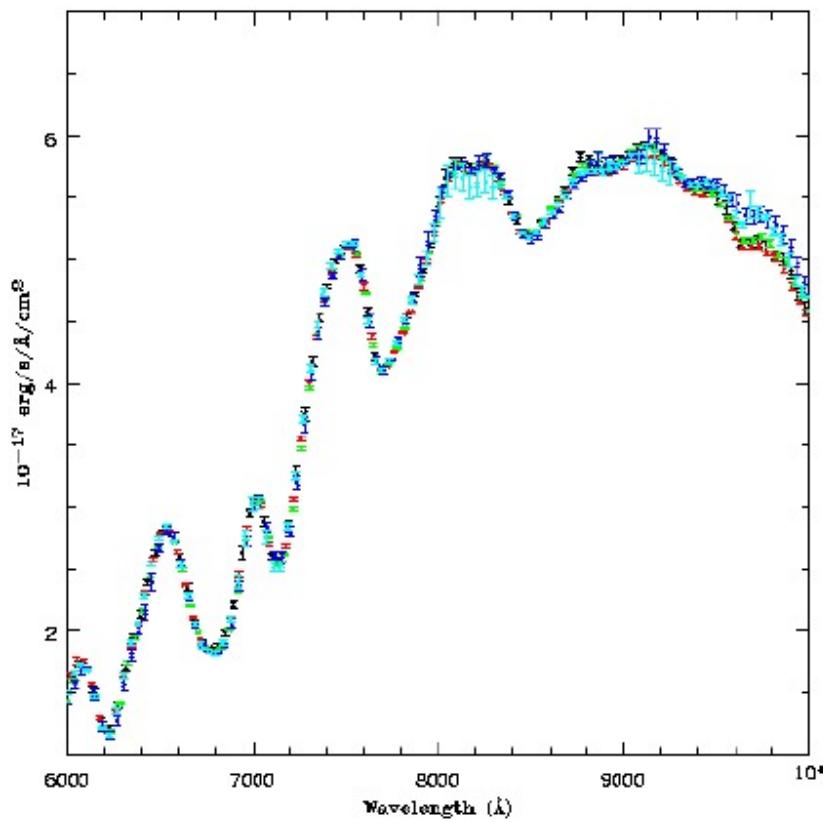
- Spectra for every source in the field.
- Good S/N continuum detections to  $I(AB) \sim 27.5$ .  
Ten times deeper than ground-based : Keck, Gemini, VLT
- about 15% of UDF sources  $\sim 1500$  spectra with good s/n
- Spectral identification of every  $z=4-7$  object to  $I(AB)=27.5$
- Moderate redshift ellipticals  $z \sim 1-2$
- Emission line galaxies
- Reduced spectra available from HST archives:



• [http://archive.stsci.edu/prepds/udf/udf\\_hlsp.html](http://archive.stsci.edu/prepds/udf/udf_hlsp.html)



## Experimental design (Pirzkal et al. 2004)

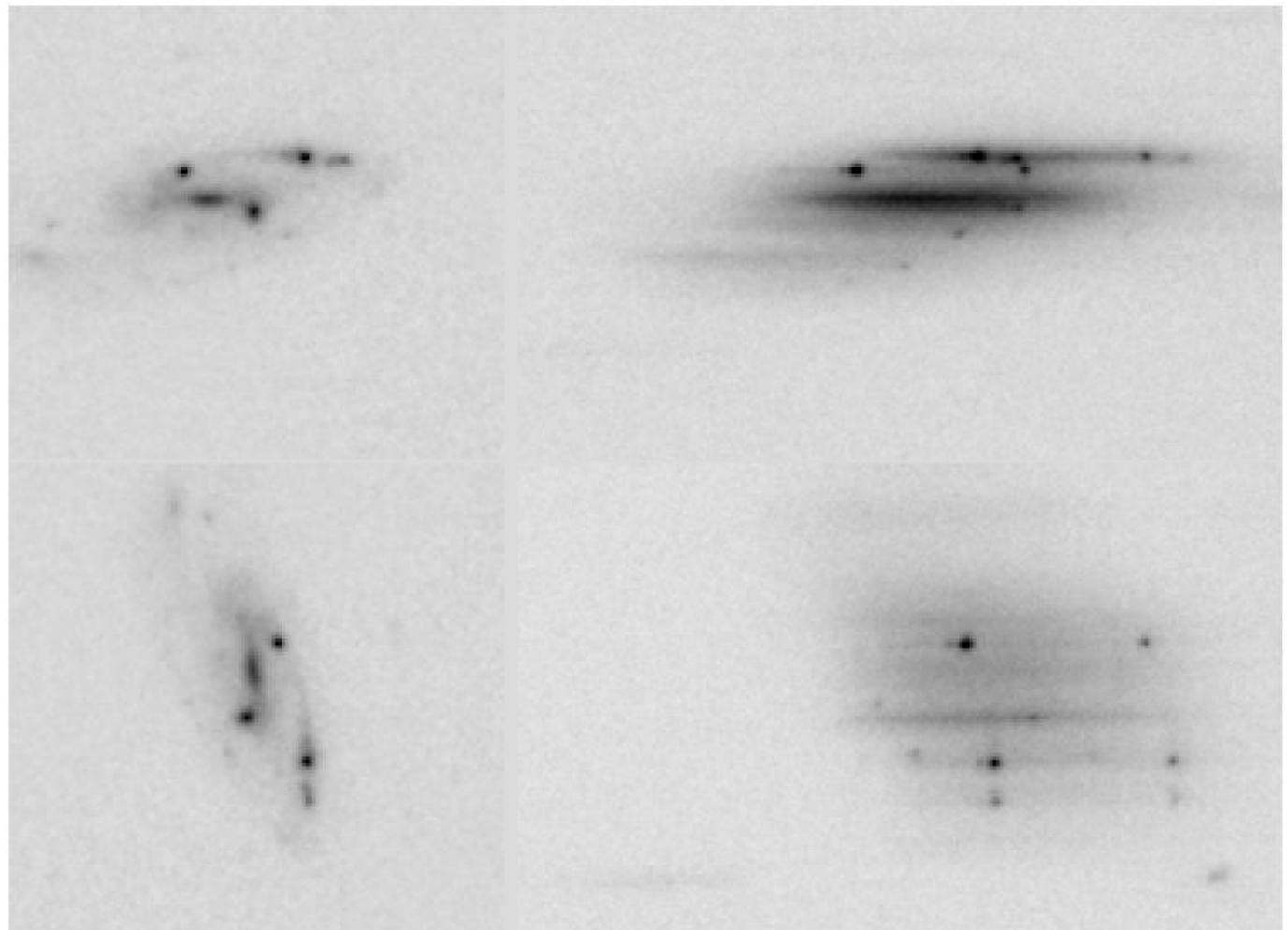
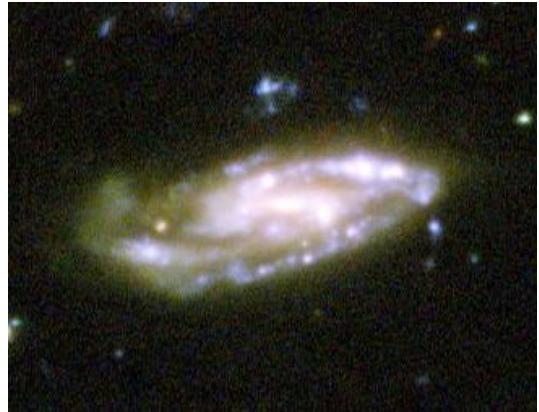


Four orients: 0, 8, 90, 98 degrees  
orient to disentangle  
overlapping spectra.

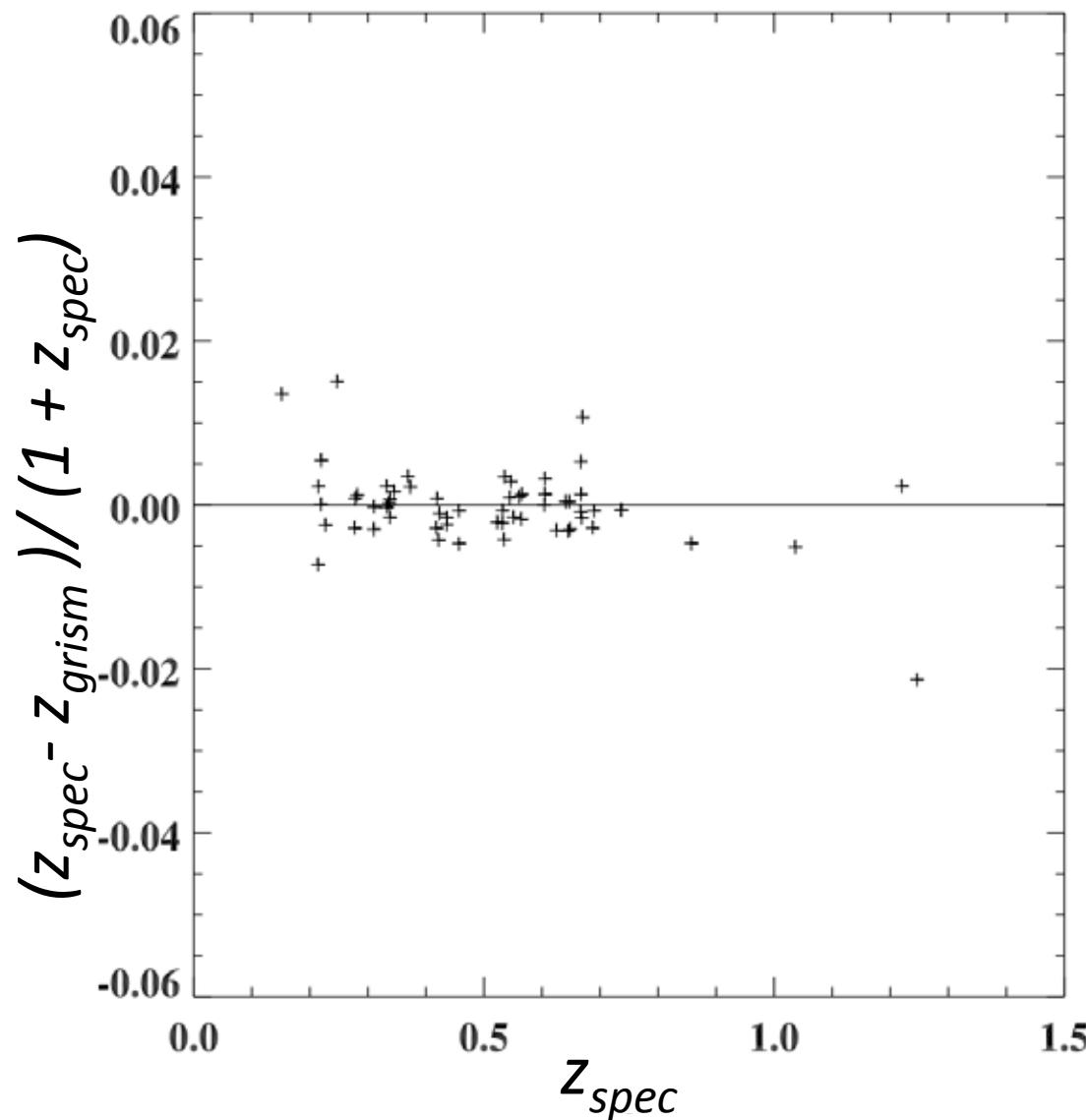
Good agreement demonstrates  
good wavelength and flux  
calibration



A Spiral galaxy at  $z=0.3$

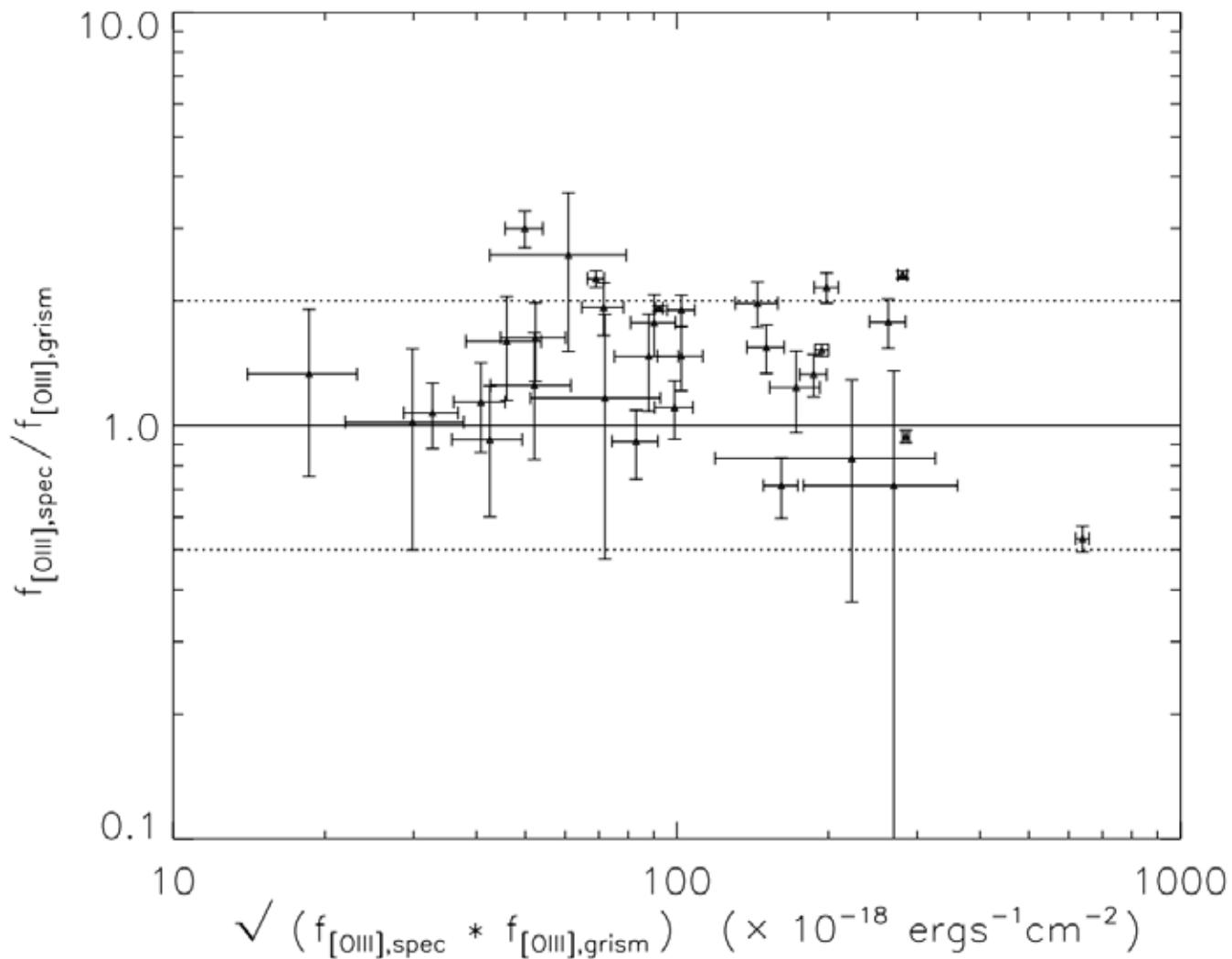


Direct image | Dispersed image



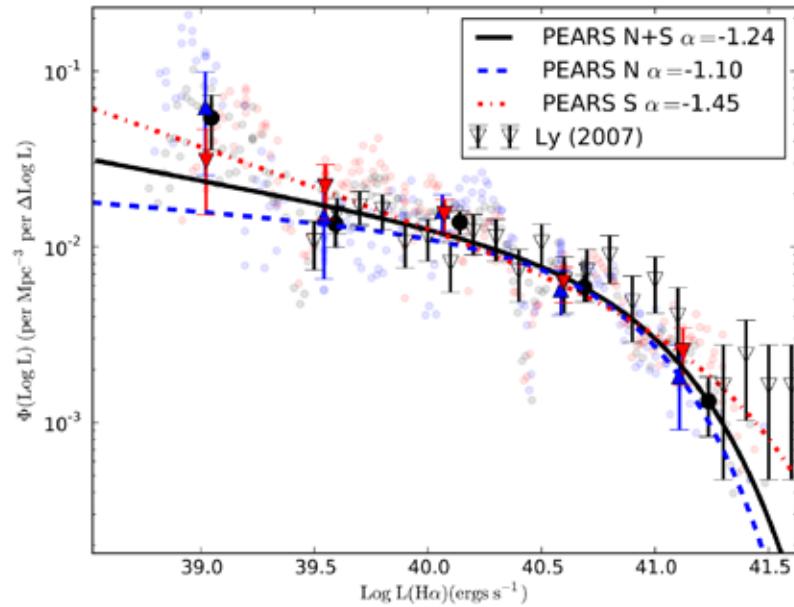
- $\sigma_z = 0.006$  for ACS grism, with  $R = 100$  (Xia et al 2011).
- This improves for  $R \sim 200$  WFC3 G102.
- Expect further improvement with  $R \sim 500$  WFIRST grism.

**Figure 3.** Redshift differences between the spectroscopic and the grism redshifts as a function of the spectroscopic redshifts. The accuracy of the grism redshift is measured to be  $\sigma_z = 0.006$ . (From Xia et al, 2011)

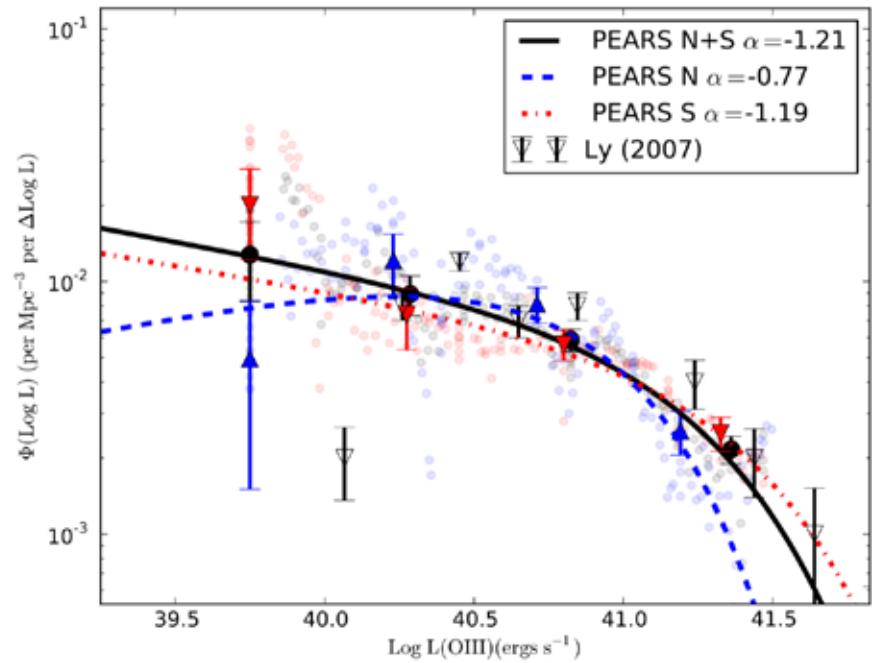


**Figure 4.** Flux ratios of the spectroscopic to the grism as a function of the square root of the [O III] line fluxes measured by ACS grism and LDSS-3, which is plotted in log scale. The ratios for most objects are in the range from 0.5 to 2.0 (the dotted lines, the solid line shows the ratio of 1), which is in the reasonable range due to the different sampling of galaxy light by the slit and grism, the uncertainty in the determination of the grism continuum.

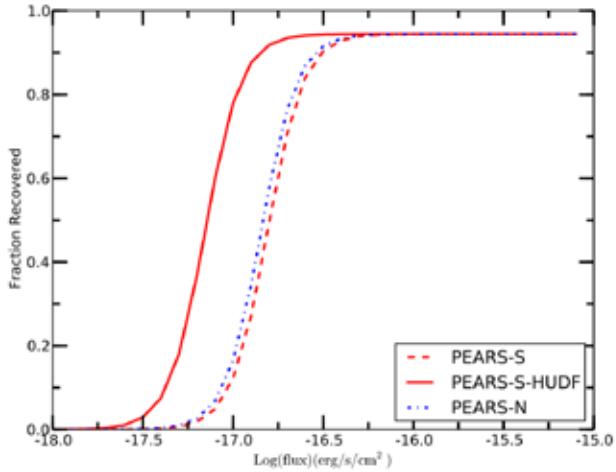
# Luminosity functions of Line emitters



Pirzkal et al. 2013



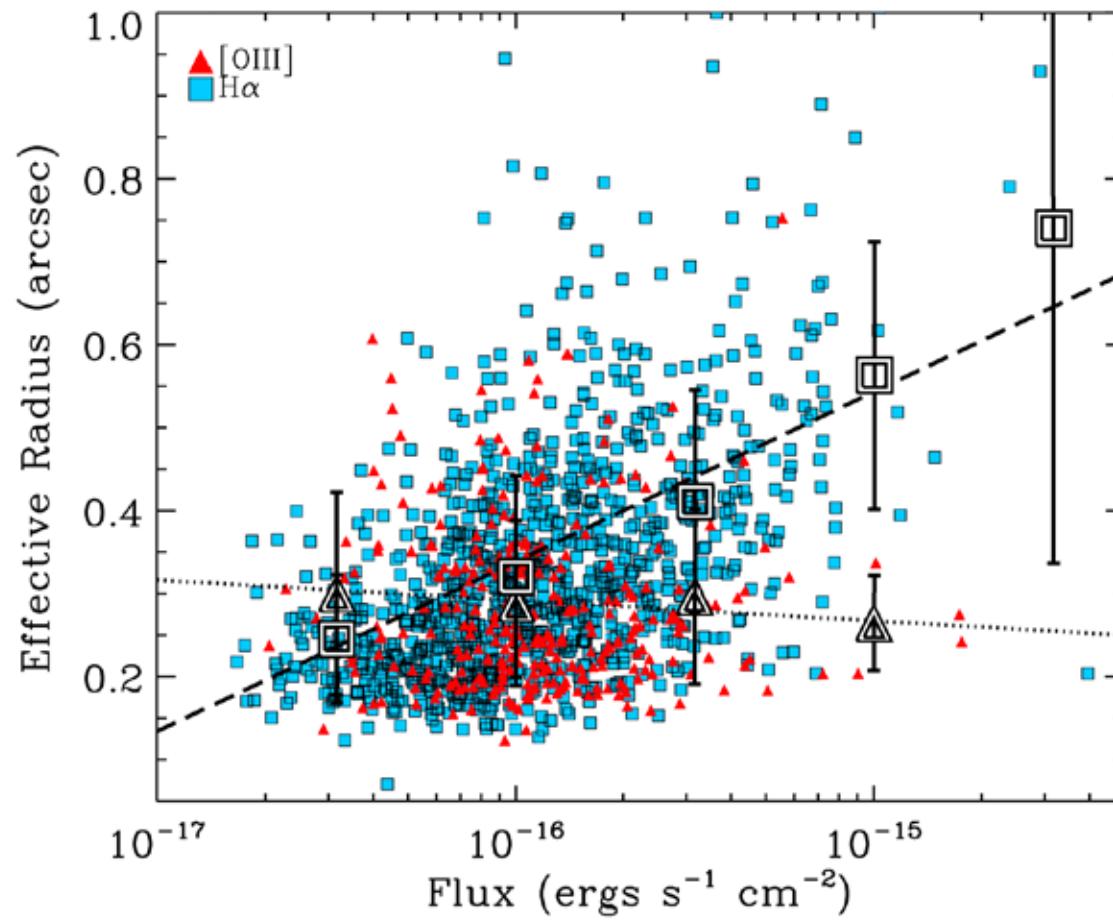
# Completeness simulations.



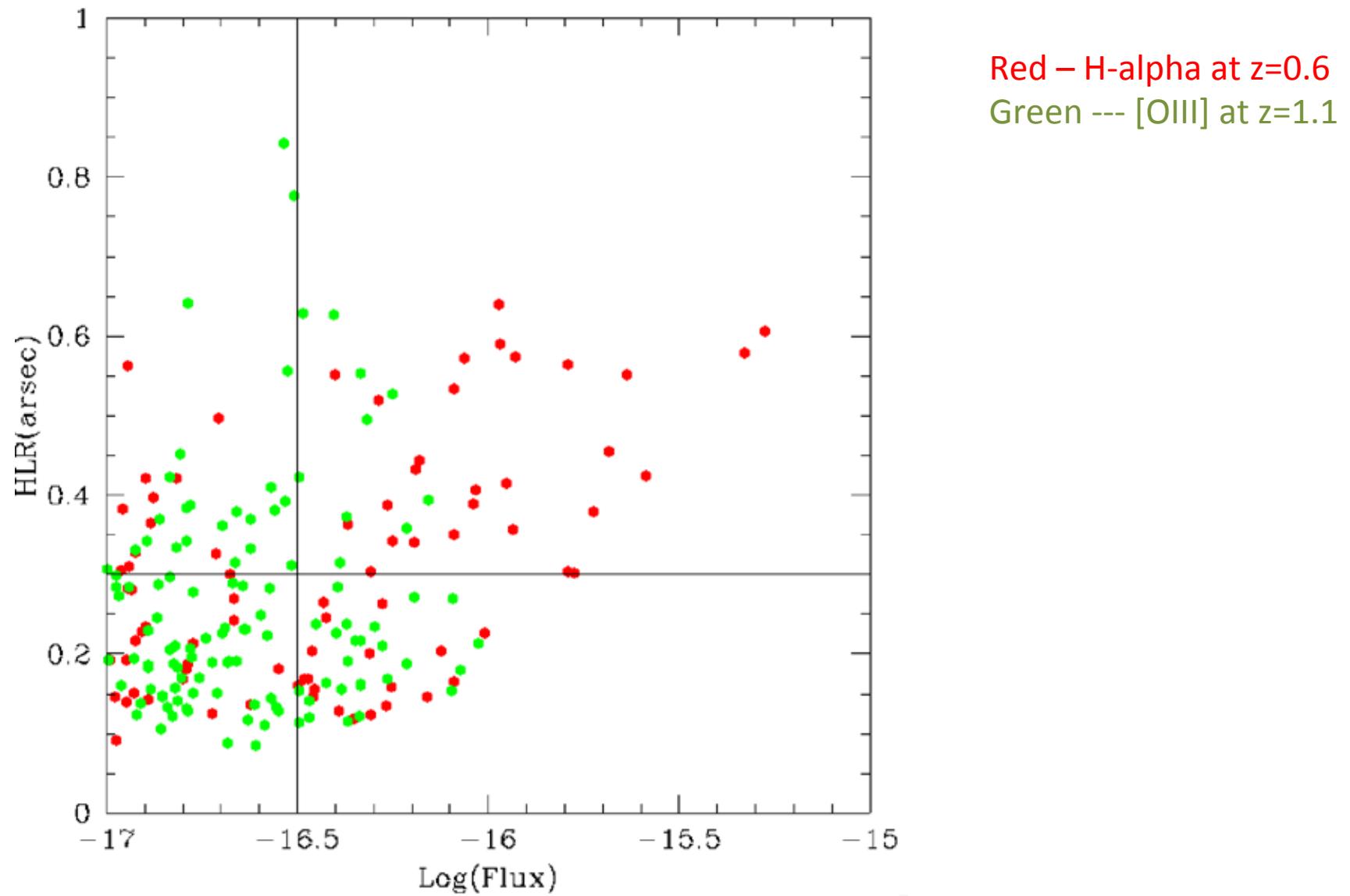
**Table 4**  
Luminosity Function

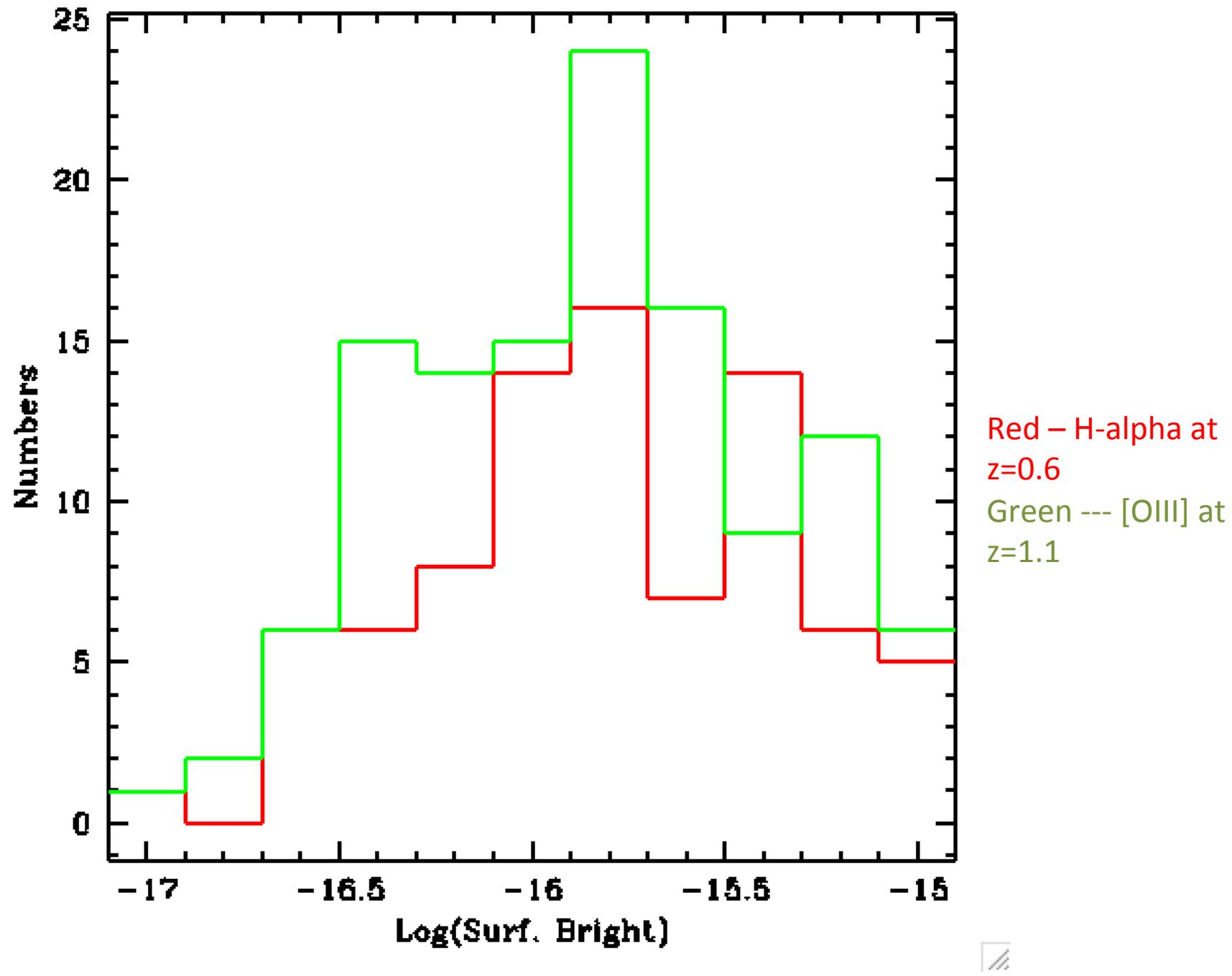
Method	Line	Redshift	PEARS-N			PEARS-S			PEARS		
			Range	$L_*$	$\alpha$	$\Phi_*$	$L_*$	$\alpha$	$\Phi_*$	$L_*$	$\alpha$
STY	O II	$0.5 < z < 1.6$	$41.45^{+1.56}_{-0.14}$	$-1.23^{+0.42}_{-0.87}$	$-4.08^{+0.45}_{-5.83}$	$41.95^{+0.48}_{-0.48}$	$-1.49^{+0.53}_{-0.35}$	$-4.88^{+0.98}_{-1.27}$	$41.75^{+0.57}_{-0.29}$	$-1.44^{+0.38}_{-0.42}$	$-4.63^{+0.52}_{-4.66}$
	O III	$0.1 < z < 0.9$	$41.65^{+0.57}_{-0.12}$	$-1.23^{+0.14}_{-0.21}$	$-3.45^{+0.30}_{-0.73}$	$41.68^{+0.36}_{-0.00}$	$-1.19^{+0.10}_{-0.23}$	$-3.44^{+0.19}_{-0.66}$	$41.67^{+0.10}_{-0.13}$	$-1.21^{+0.11}_{-0.12}$	$-3.45^{+0.21}_{-0.42}$
	H $\alpha$	$0.0 < z < 0.5$	$41.01^{+0.43}_{-0.22}$	$-1.14^{+0.26}_{-0.29}$	$-2.99^{+0.39}_{-1.52}$	$40.83^{+0.01}_{-0.24}$	$-0.86^{+0.29}_{-0.18}$	$-2.50^{+0.32}_{-0.27}$	$40.90^{+0.07}_{-0.03}$	$-0.97^{+0.11}_{-0.19}$	$-2.72^{+0.16}_{-0.43}$
1/ $V_{\max}$	[O II]	$0.5 < z < 1.6$	$44.46^{+0.54}_{-0.14}$	$-1.84^{+0.11}_{-0.15}$	$-6.30^{+0.06}_{-1.03}$	$44.35^{+0.65}_{-1.61}$	$-1.93^{+0.12}_{-0.10}$	$-6.62^{+1.59}_{-0.94}$	$43.24^{+1.76}_{-1.07}$	$-1.93^{+0.14}_{-0.08}$	$-5.49^{+1.24}_{-1.99}$
	[O III]	$0.10 < z < 0.90$	$40.87^{+0.07}_{-0.13}$	$-0.77^{+0.23}_{-0.10}$	$-2.17^{+0.08}_{-0.12}$	$41.45^{+0.21}_{-0.17}$	$-1.19^{+0.15}_{-0.12}$	$-2.67^{+0.15}_{-0.22}$	$41.31^{+0.09}_{-0.09}$	$-1.21^{+0.08}_{-0.07}$	$-2.58^{+0.09}_{-0.09}$
	H $\alpha$	$0.00 < z < 0.49$	$40.89^{+0.13}_{-0.17}$	$-1.10^{+0.13}_{-0.11}$	$-2.36^{+0.11}_{-0.21}$	$41.42^{+0.44}_{-0.26}$	$-1.45^{+0.06}_{-0.10}$	$-2.89^{+0.14}_{-0.44}$	$41.01^{+0.06}_{-0.09}$	$-1.24^{+0.05}_{-0.04}$	$-2.47^{+0.07}_{-0.07}$

# Colbert et al. 2013.



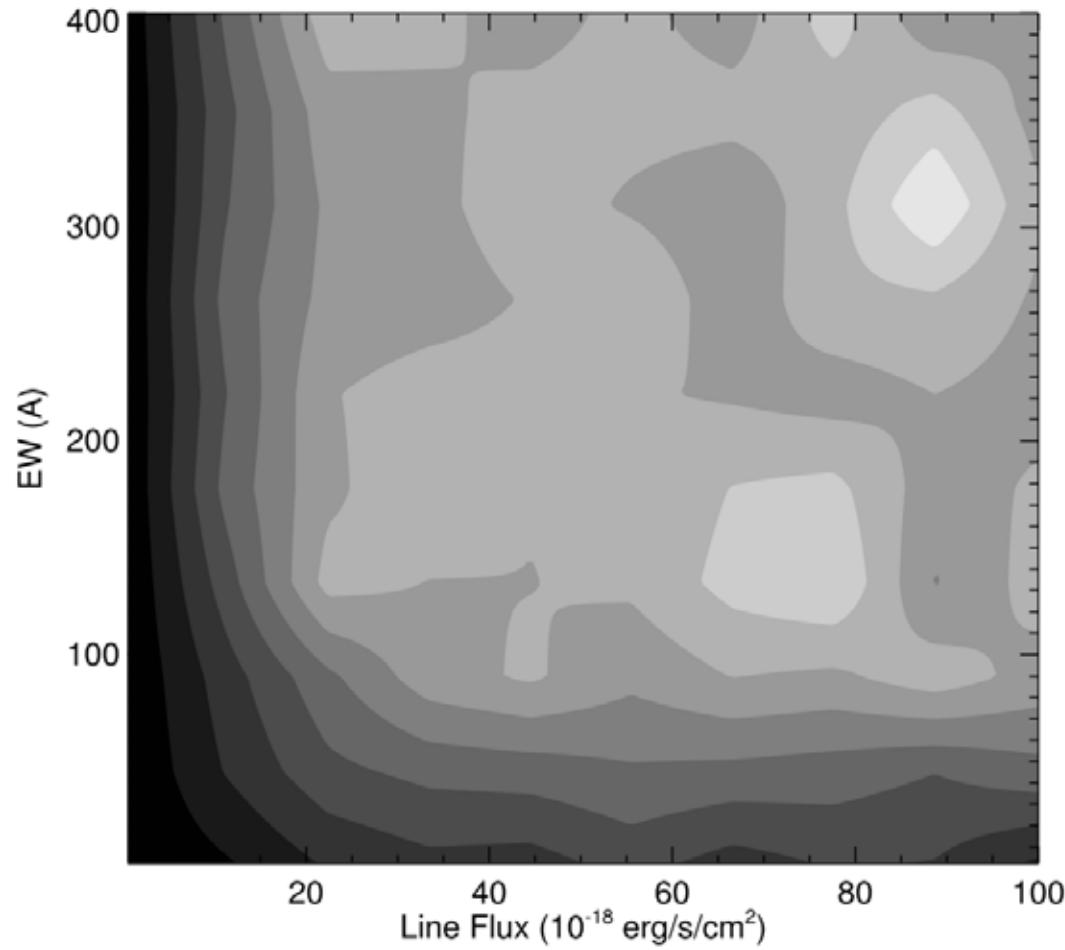
# Does Size matter?





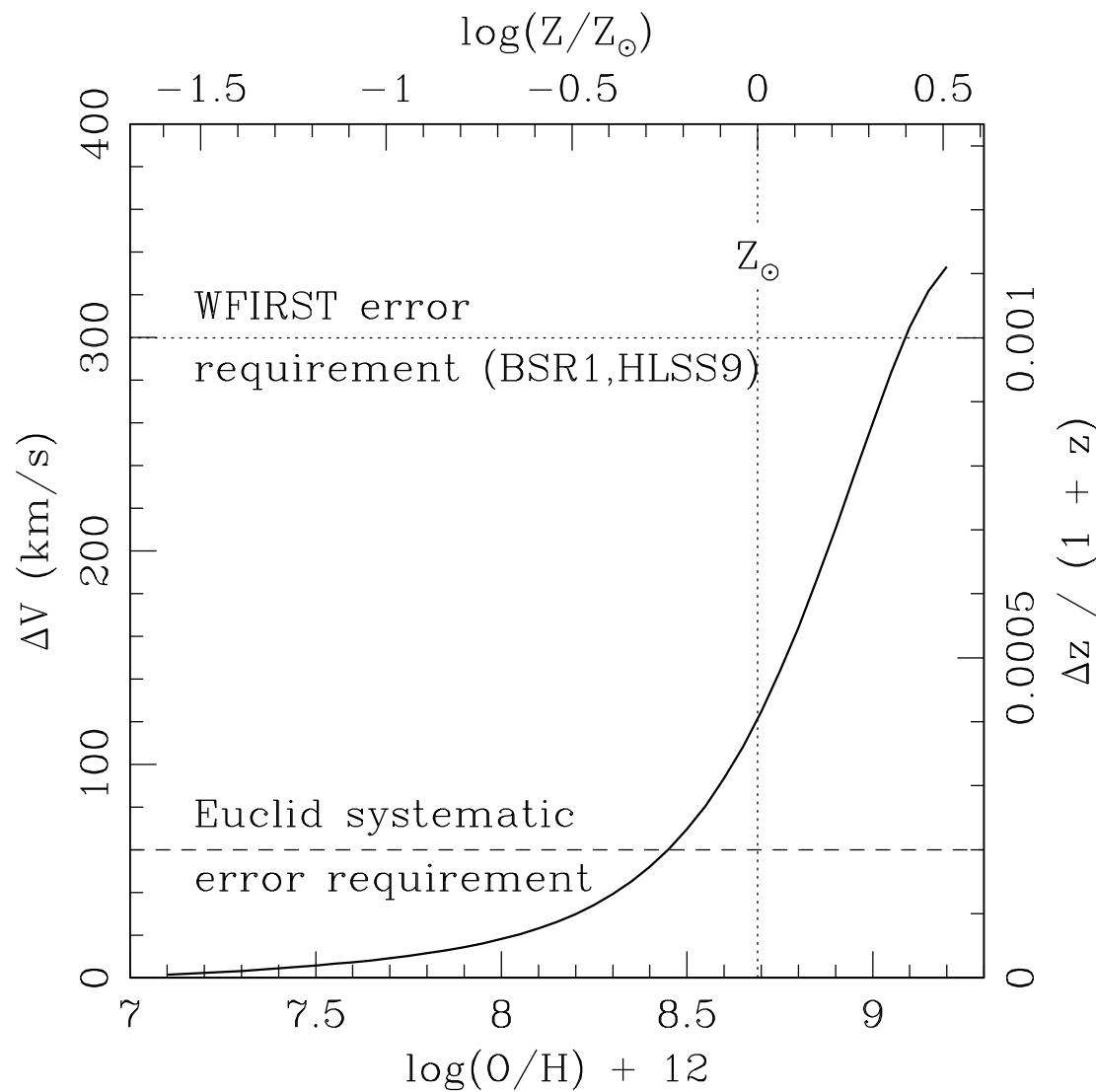
# Equivalent Width matters

related to source size, dispersion per pixel, size of pixels...



Completeness plots  
from Xu et al. 2007  
(Grapes emission  
line catalogs)

# Metallicity (mass?) Effects

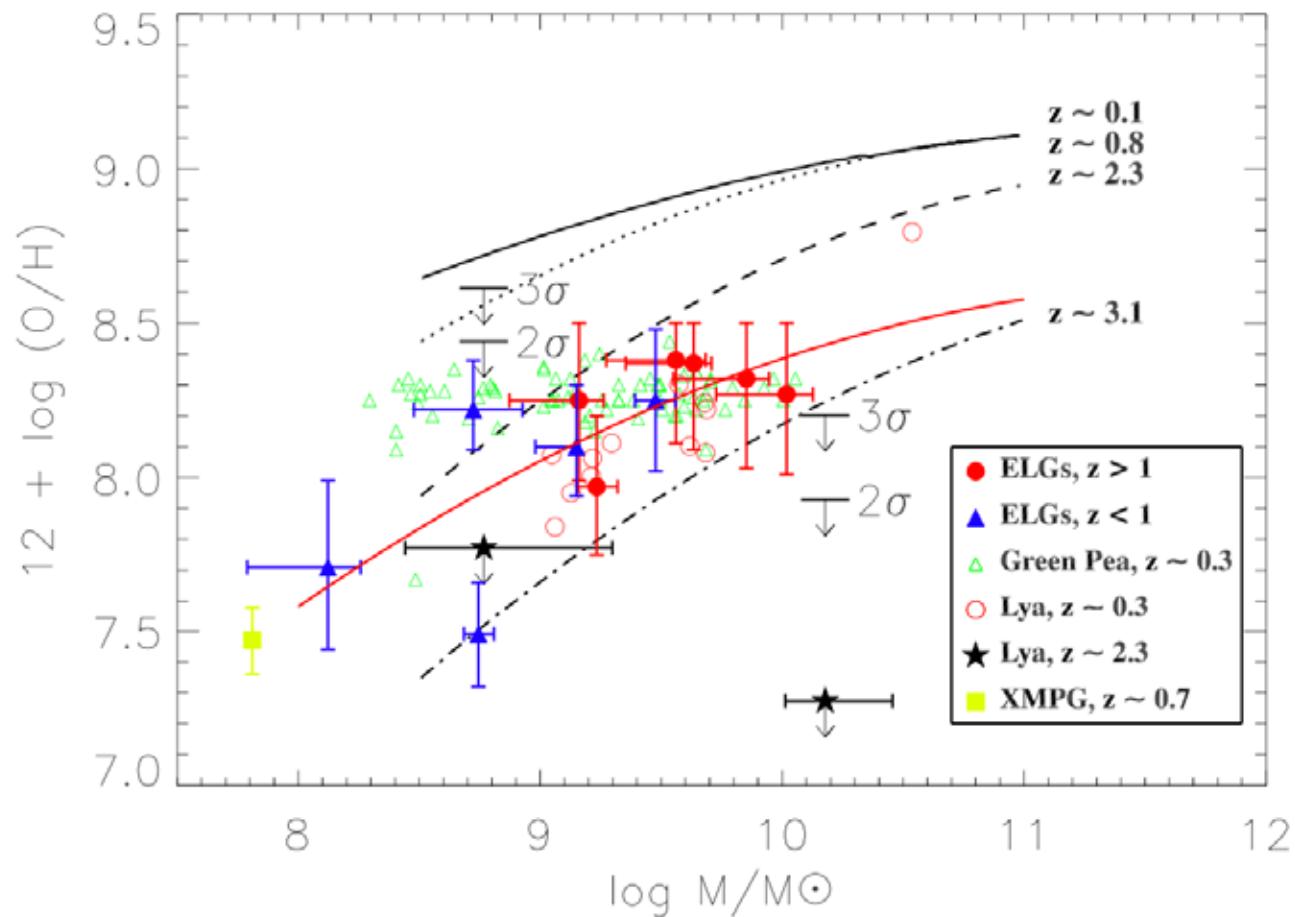


When H $\alpha$  and [NII] lines are blended, there is a metallicity dependent shift in line centroid.

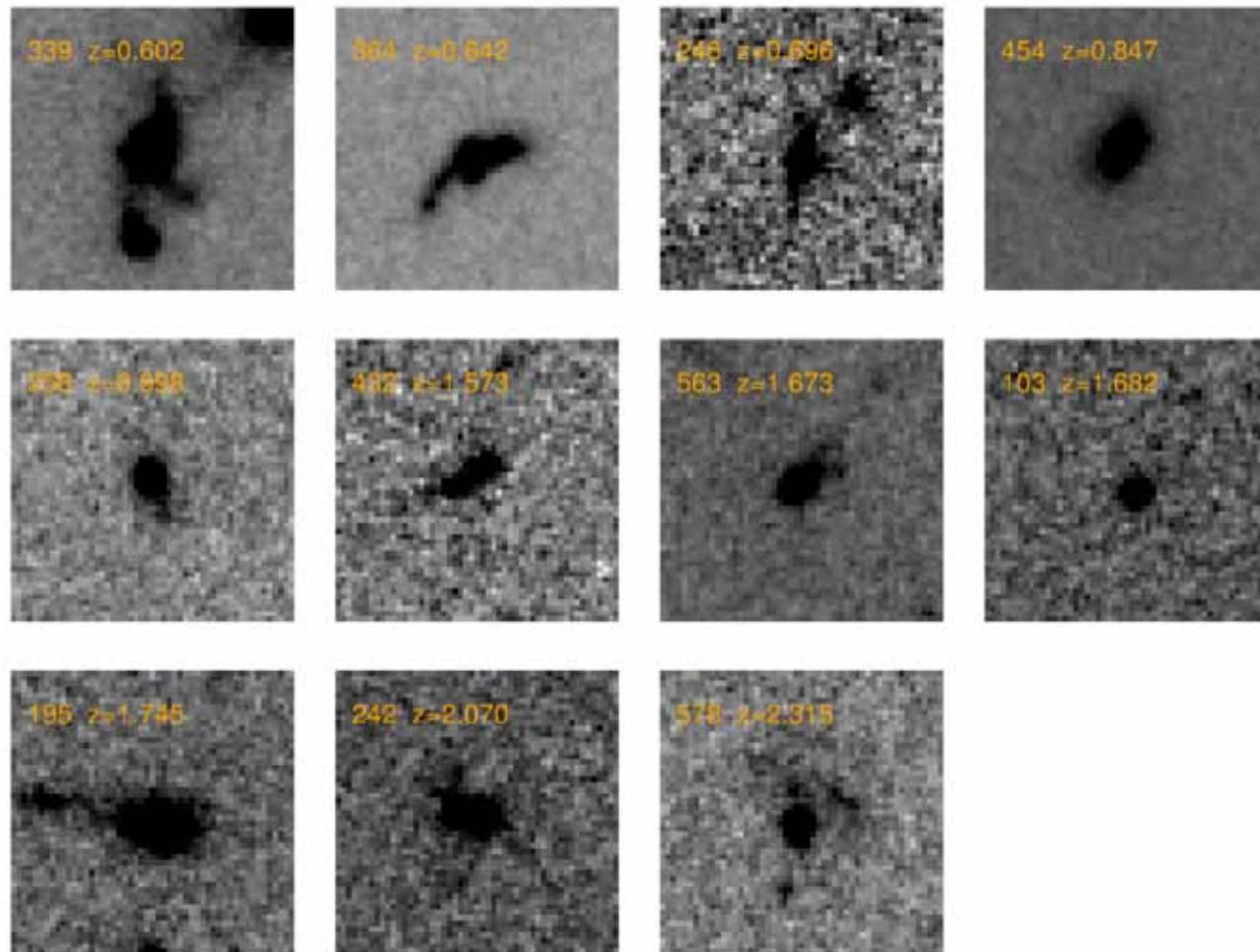
Here we plot the velocity shift as a function of metallicity.

This matters for sources larger than about 0.4" in WFIRST. For smaller sources, [NII] and H $\alpha$  are cleanly resolved.

# Mass-metallicity of emission line galaxies (Xia et al. 2013, Finkelstein et al. 2009, Green peas....)

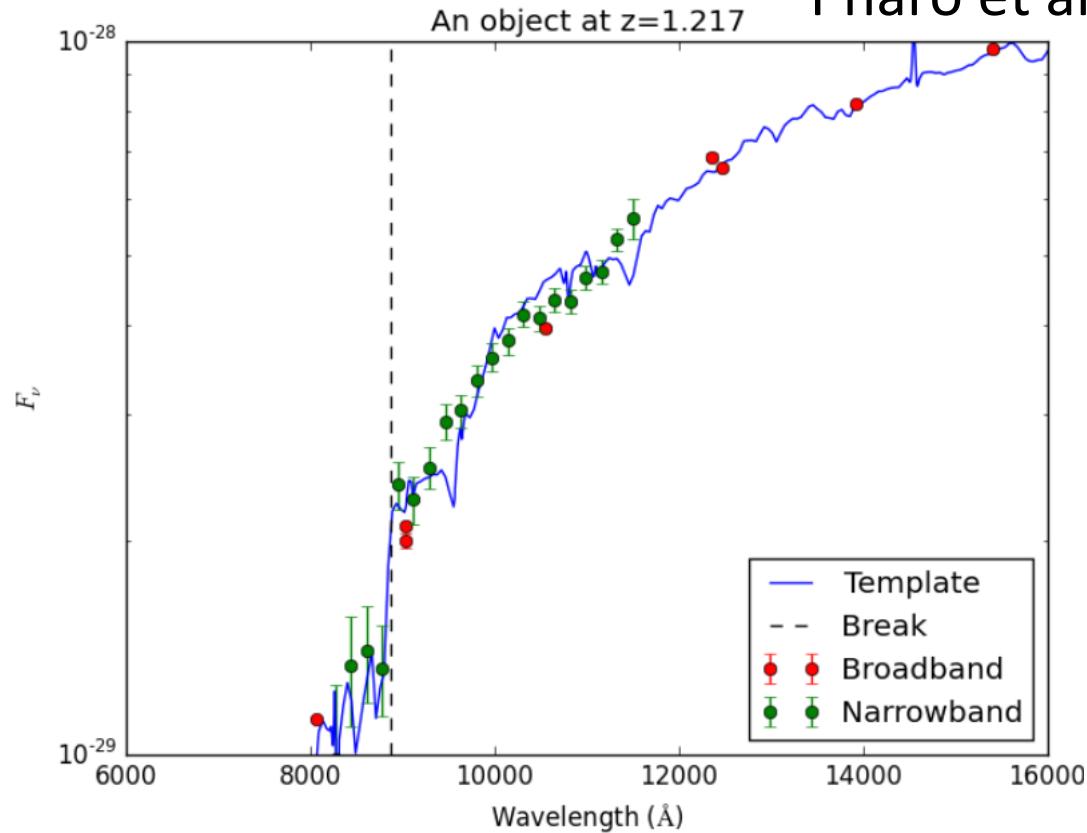


# Morphologies of Emission line galaxies are irregular (Xia et al. 2013)

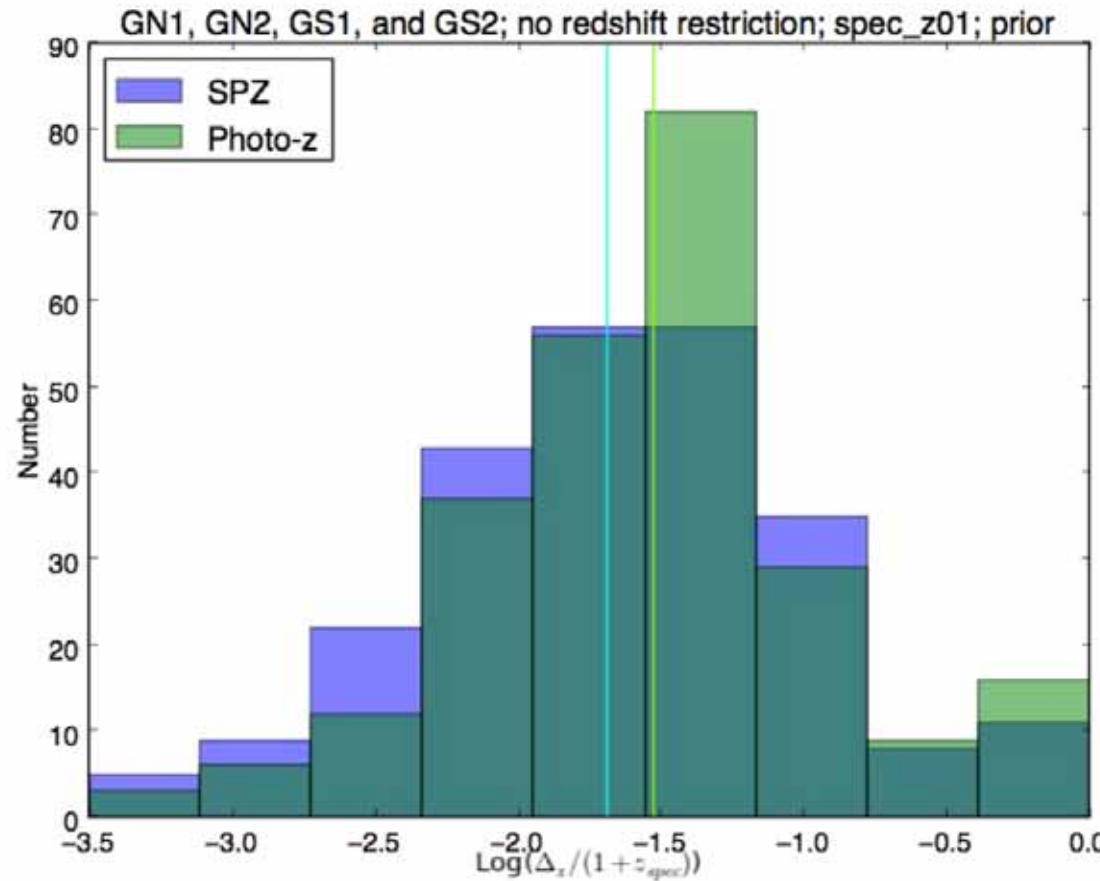


What If there is no line?  
to We do what we call Spectro-photo-z's (SPZs)

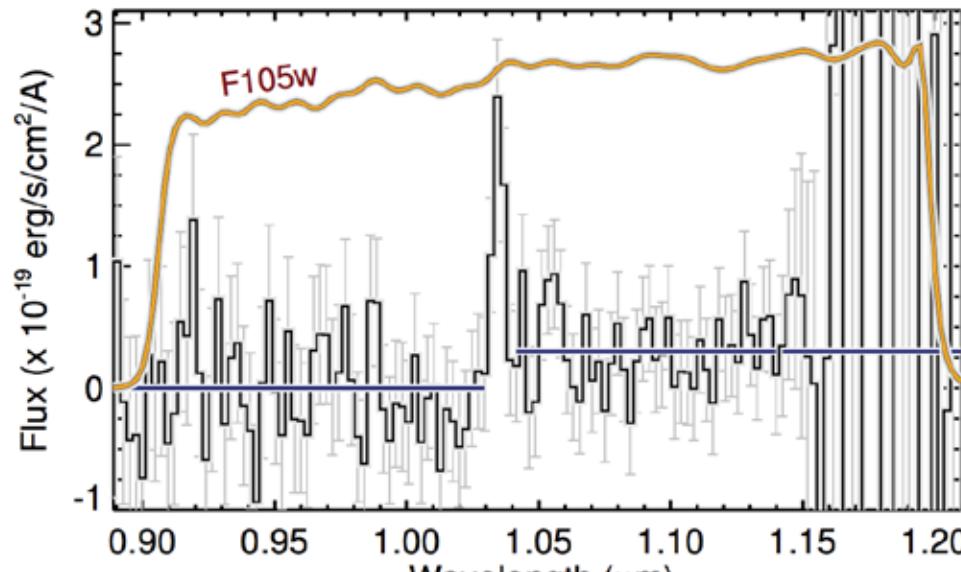
Ryan et al. 2007  
Brammer et al. 2013.  
Pharo et al. (in prep)



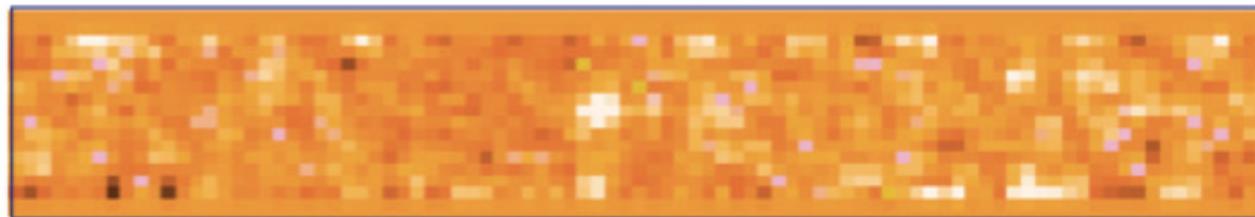
Grism data improves photo-z's compared to just broadband – 2% vs 3%, and many fewer outliers.  
(Pharo et al. in prep)



# Faint Infrared Grism Survey (FIGS)



Tilvi et al. 2016, submitted to  
ApJ.



Tilvi et al. 2016, also poster at this meeting.

